NANOCRYSTALLINE DIAMOND ON $LiNBO_3$ FOR SURFACE ACOUSTIC WAVE APPLICATIONS

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Abstract

The growth of the nanocrystalline diamond (NCD) films on $LiNbO_3$ (LN) substrate using $CH_4/H_2/O_2$ in microwave plasma enhance chemical vapor deposition reactor have been investigated in this study. By varying the temperature, gas composition, and processing pressure during the growth, it is concluded that smooth NCD films on LN substrates can be obtained by MPECVD with an amorphous buffer layer. Furthermore, the nucleation density can be substantially enhanced by applying a bias voltage at the initial stage of the growth. Preliminary measurement of surface acoustic wave (SAW) characteristics on the above mentioned structure concluded that NCD/LN structure is ideal for high electromechanical coupling, which is highly desirable for SAW devices. Further study on various device architectures is proposed in this paper.

INTRODUCTION

NCD deposition using MPECVD has been demonstrated by many laboratories in the past decade. In this report, we demonstrate the growth condition for NCD on LiNbO3 substrate. An attempt to make SAW devices using NCD/LN is also demonstrated.

EXPERIMENT

The substrates were as-received LN wafers. In order to increase nucleation density, the substrates were scratched with 4-nm diamond powders to reduce surface energy and provide nucleation seeds. After that, they were subsequently cleaned ultrasonically in acetone, methanol and D.I. water in sequence and then dipped in a 10% HF aqueous solution, and dried by blowing nitrogen before the deposition. When the chamber vacuum achieves 1×10^{-3} Torr, hydrogen was inducted into the chamber to produce hydrogen plasma at 20 Torr at 1 kW microwave power. Hydrogen plasma etches oxides on substrates surface for pretreatment before deposition. Nanocrystalline diamond films were deposited using micro-wave plasma enhanced chemical vapor deposition (MWPECVD) system made by Astex Company. A schematic diagram of this system is shown in Fig. 1. Microwave generated by the generator was guided through quartz window into the chamber to to produce plasma. The substrate was put on a molybdenum holder, and a boron nitride heater provided independent substrate heating. Thermocouple placed underneath the molybdenum holder was used to monitor the substrate temperature. In order to measure the surface temperature of the substrate, a two-color pyrometer was used.

RESULTS

Fig. 1 shows the SEM image of diamond thin films that grown at 610 ℃ with smooth surface. The diamond growth rate increased with increasing temperature and as shown in Table 1. The grain size of the film grown above 610 ℃ showed no variation with increasing growth temperature. From the SEM cross-section images we can observe that the diamond grown below 580 ℃ has columnar morphology and the diameter of the columns increase during the growth. The diamonds grown above 610 ℃ are still columnar in nature, however, the diameter of the columns stayed constant during growth. The presumable cause is because higher temperature offered enough energy to facilitate continuous secondary nucleation and restrain the grain growth.

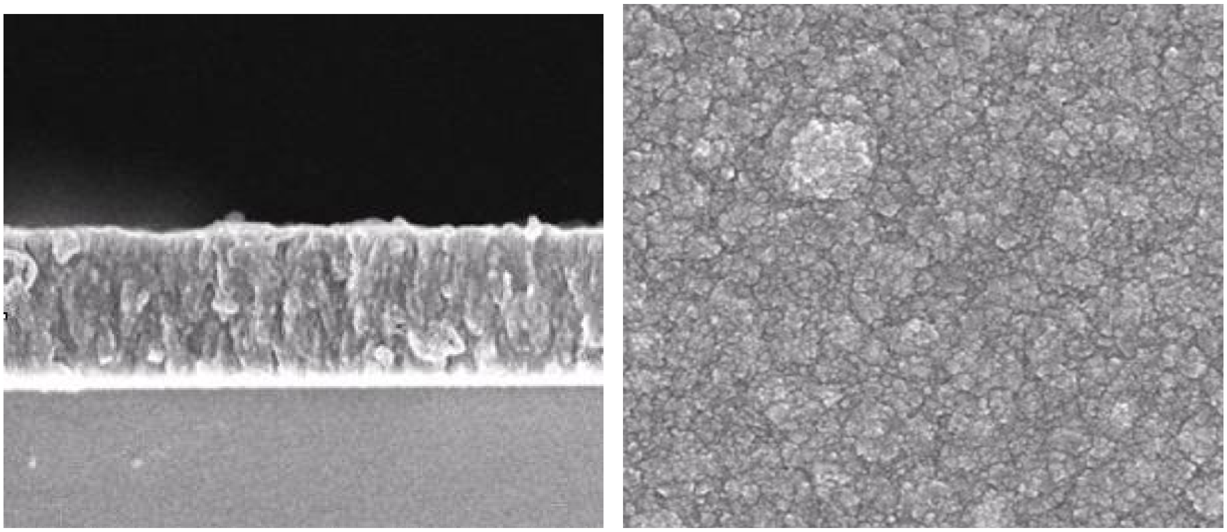

Figure* 1. *The SEM images (a) cross-section view and (b) top view images of diamond films grown at 610 ℃.

Fig. 2 shows the hardness and elastic modulus of the diamond thin films at various growth temperatures measure by nanoindentation system. Hardness and elastic modulus increased with temperature. The film grown at 750 ℃ showed the highest hardness (~49GPa) and elastic modulus (~482GPa). The hardness of nanocrystalline diamond films measured by nanoindentation was lower than the hardness of natural diamond (100GPa) [5]. The presumable cause is high proportion of non-diamond phase that exist in grain boundary surrounding the nanocrystalline diamond. Surface acoustic wave technique was also employed by Professor Peter Hess's group at Heidelberg Univresity, Germany, to measure the Young's modulus of the films. A Young's modulus and density of 746 GPa and 3.45 g/cm^3, respectively, were measured for the film grown at 610 ℃.

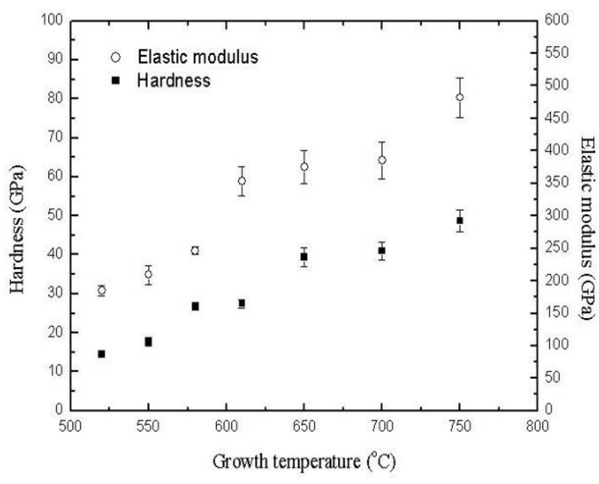

Figure* 2. *Hardness and elastic modulus of diamond thin films grown at various temperatures.